## 6. Climate Change and Diffuse Pollution Mitigation

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### 6.1 Introduction

Agriculture continues to be a significant source of diffuse water pollution and greenhouse gas emissions in Wales; whilst some agricultural practices are also responsible for losses and gains of soil carbon. The Welsh Government has set national targets to improve water quality and reduce greenhouse gas emissions, and the agricultural sector is expected to contribute to the meeting of these targets. In consequence, the Glastir scheme has been developed with sufficient flexibility to target priority themes (such as soil carbon) in a spatial context, and introduce options on farms to e.g. enhance carbon sequestration, reduce greenhouse gas emissions and diffuse water pollution from the agricultural sector. The Welsh Government has prioritised funding for options focussed on climate change mitigation and diffuse water pollution for Years 1 and 2 of the scheme.

As a first step to determine the potential impacts of Glastir on greenhouse gas and diffuse pollution emissions and carbon sequestration, the Welsh Government tasked the Glastir Monitoring and Evaluation project to assess the potential impact of Glastir options on these priority areas through modelling (including emission source not included in the greenhouse gas inventories), work to identify the wider benefits of the Glastir Efficiency Grants and a scoping study to identify barriers for uptake of the Woodland Creation Scheme (see chapter 3). The Year 1 GMEP Report provided an initial description of the *modelling ensemble* approach we used (the full report on the models used is provided as Appendix 5.6 in that report) with model outputs for three uptake scenarios presented for five Glastir options. Below we give a broad overview of greenhouse gas emissions for land use and agriculture in Wales as an introduction and then outline Year 2 activities. For work on diffuse pollution see Year 1 report and Chapter 10 (Emmett et al. 2014).

#### *6.1.1 Overview of Greenhouse Gas Emissions from Agricultural Land Use in Wales and the contribution from different sectors*

In 2012, Agriculture contributed 13% of $CO_2$e emissions in Wales, with $CH_4$ and $N_2O$ representing 64% and 79% of total Welsh emissions of these two gases, respectively. In total, 6,142 kt $CO_2$e were emitted by agriculture in Wales in 2012; comprising 47% as $CH_4$ (2,864 kt $CO_2$e), 44% as $N_2O$ (2,707 kt $CO_2$e), and the remainder associated with transport (AEA, 2014).

*6.1.1.1 Methane*

Enteric fermentation by ruminant livestock contributed >80% of total agricultural $CH_4$ emissions in Wales (2,294 kt $CO_2$e), manure management representing the remaining $CH_4$ emission. Dairy and beef cattle were responsible for 63%, and sheep 34% of agricultural $CH_4$ emissions (Figure 6.1.1.1.1). Manure management, although an important source of $CH_4$, represents only around 20% of the total $CH_4$ emissions.

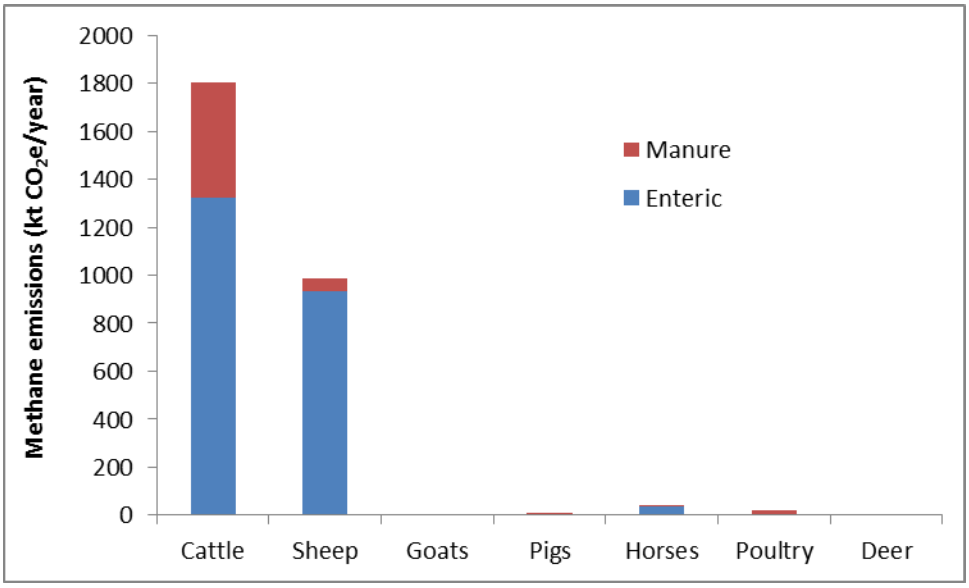


**Figure 6.1.1.1.1** *Methane emissions from livestock sectors in Wales (2012) [Source: NAEI, 2013].*

### 6.1.1.2 Nitrous oxide

Agriculture is the dominant source of $N_2O$ in Wales, with >90% (2,491 kt$CO_2$e) of this arising from agricultural soils. The key sources of $N_2O$ from agricultural soils are direct $N_2O$ emissions from the soil to the atmosphere following fertiliser nitrogen, grazing returns (in the form of dung and urine) and manure applications. However, a proportion of nitrogen that is deposited to soil from the atmosphere (in wet and dry deposition) is subsequently emitted as $N_2O$ from the soil, whilst $N_2O$ is also emitted from leached nitrate in watercourses. $N_2O$ emissions from deposited N and nitrate leaching are known as 'indirect' soil losses. Table 6.1.1.2.1 illustrates the significance of indirect $N_2O$ emissions, especially those associated with nitrate leaching.

| **$N_2O$ (kt $CO_2$e)** | **Direct** | **Indirect** | |
|---|---|---|---|
| | | Leaching | N deposition |
| Fertiliser | 403 | 269.7 | 37.2 |
| Grazing returns | 895.9 | 334.8 | 89.9 |
| Manure application | 186 | 142.6 | 37.2 |
| Crop residues | 31 | 0 | 0 |
| Biological fixation | 0 | 0 | 0 |
| Improved grassland | 27.9 | 0 | 0 |
| Histosols | 0 | 0 | 0 |
| Sewage sludge | 12.4 | 9.3 | 3.1 |
| Total | 1556.2 | 756.4 | 167.4 |

**Table 6.1.1.2.1** *Sources of $N_2O$ from agricultural soils in Wales (2012)*

The cattle (dairy+beef) sector is responsible for 65% of the total $N_2O$ emissions from Welsh agriculture (Table 6.1.1.2.2.). Direct soil emissions from fertiliser nitrogen and manure nitrogen applications, and following urine and dung deposition by grazing livestock represents 57% of the total $N_2O$ emissions from Welsh agriculture. Indirect $N_2O$ losses associated with nitrate leaching to water courses, and nitrogen deposition from the atmosphere, represent 34% of the total agricultural emission, while $N_2O$ emissions from manure management in livestock buildings and manure stores are relatively small sources, ca. 9%. Therefore, options taken to reduce indirect $N_2O$ emissions, e.g. nitrate leaching, will reduce the total $N_2O$ emission from Welsh agriculture.

| kt $CO_2e$ | Total | Direct | Indirect | Manure management |
|---|---|---|---|---|
| Cattle | **1100.5** | 573.5 | 347.2 | 179.8 |
| Sheep | **672.7** | 440.2 | 213.9 | 18.6 |
| Pigs | **3.1** | 0 | 0 | 3.1 |
| Horses | **74.4** | 49.6 | 24.8 | 0 |
| Poultry | **71.3** | 18.6 | 18.6 | 34.1 |
| Sewage sludge | **24.8** | 12.4 | 12.4 | 0 |
| Fertiliser | **709.9** | 403 | 306.9 | 0 |
| Crop residues | **31** | 31 | 0 | 0 |
| Improved Grassland | **27.9** | 27.9 | 0 | 0 |
| Total | **2715.6** | 1556.2 | 923.8 | 235.6 |

**Table 6.1.1.2.2** *Nitrous oxide emissions from livestock sectors in Wales (2012) [Source: NAEI, 2013].*

### *6.1.2 National Trends from the Land Use and Agriculture Sectors*

#### *6.1.2.1 Agricultural Greenhouse Gas Emissions*

Agricultural sector GHG emissions in Wales have decreased by >20% since 1990 (see Figure 6.1.2.1.1). There was a small increase of less than 1% in emissions from 2011 to 2012 mainly due to a 1% reduction in cattle numbers balanced by an increase of 3% in sheep numbers. The overall trend in reductions of ($N_2O$) emissions from soil have been the result of reductions in fertiliser nitrogen use (particularly in grasslands) and reduced numbers of livestock (manures and urine deposition) over the past decade. Current (2012) annual emissions of $N_2O$ for Wales are 2707 kt $CO_2e$ (8.73 kt $N_2O$). The trend in the reduction of livestock numbers has also resulted in lower $CH_4$ emissions. The stabilisation of numbers in recent years means that there has been little change in emissions between 2011 and 2012 (0.2% increase).

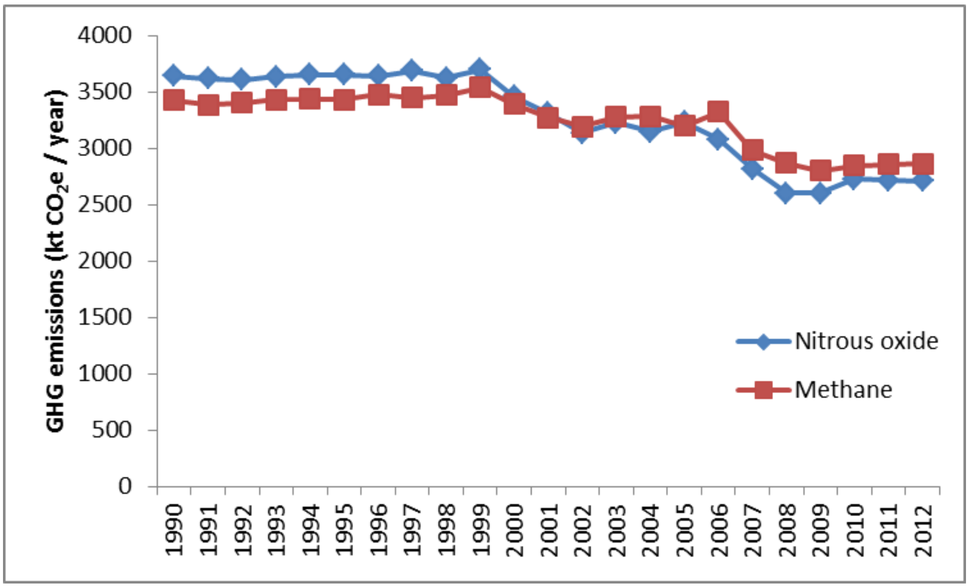


**Figure 6.1.2.1.1** *Total Annual Nitrous Oxide and Methane Emissions from Welsh Agricultural Sector inventory, 1990-2012. Source: NAEI, 2013.*

#### *6.1.2.2 Land Use, Land Use Change and Forestry(LULUCF)*

Whilst Wales is a small net sink of greenhouse gases from LULUCF activities, Figure 6.1.2.2.1 shows land which is a net greenhouse gas sink. Between 1990 and 2012, the carbon sink in Welsh grassland has increased slightly (emissions have become more negative), while emissions from cropland have decreased. These trends reflect net conversion of cropland to grassland dating back several decades, as it takes many years for the amount of carbon stored in soils to stabilise after conversion between one land use and another.

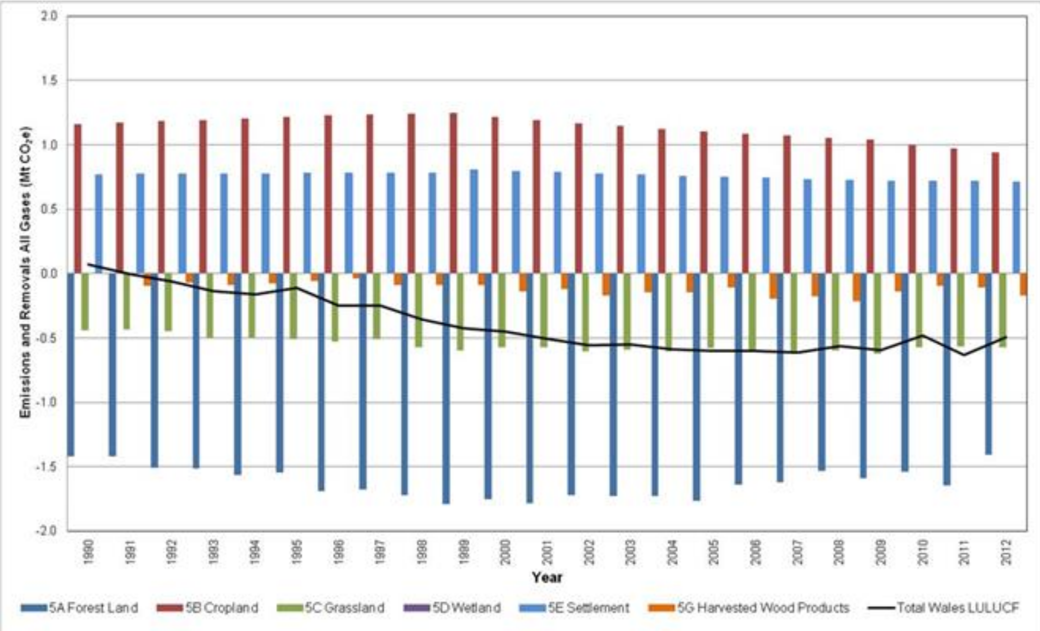


**Figure 6.1.2.2.1** *Annual Emissions from LULUCF in Wales. Source: AEA (2014) - Emissions and Removals of Greenhouse Gases from Land Use, Land Use Change and Forestry (LULUCF) for England, Scotland, Wales and Northern Ireland: 1990-2012.*

**6.2 Year 1 Achievements and Year 2 Aims and Highlights**

***6.2.1 Reminder of the Overall Achievements in Year 1***

- In year 1 we brought together an ensemble of models to assess the potential of Glastir options to reduce GHG emissions, store carbon and reduce diffuse water pollution from agriculture
- The initial runs of four Glastir options with the Bangor footprinting life cycle approach on 16 model farms showed that the carbon footprint could be reduced by between 0-24% (combined effect of direct within-farm emissions and embedded emissions associated with feed and fertiliser production). Reductions in greenhouse gas emissions are associated with measures that reduce fertiliser nitrogen use and reductions in livestock numbers.
- The ADAS modelling tool was used at the national scale for five Glastir options to assess potential changes in gaseous emissions (nitrous oxide, methane) and diffuse water pollution (nitrogen, phosphorus and sediment). GHG emissions could be reduced by a maximum of X% (if maximum adoption of the zero N fertiliser Glastir option was achieved)
- Datasets for future spatial GHG and C sequestration were acquired in preparation for the ECOSSE model
- We planned the approach for assessing the impact of Glastir Efficiency grants on i) the carbon footprint of farms which have made use of them, and ii) the wider (off-farm) benefits to the rural economy
- We developed a draft protocol for the repeat Wales Farm Practice Survey, including the proposed stratification strategy, for discussion with funders and the wider project team

### *6.2.2 Year 2 Aims*

- Provide an indication of relative GHG emissions from different farm types in Wales, and complete a more comprehensive assessment of the effect of limited Glastir options on the carbon footprints of model farms, typical of Welsh agriculture
- Assess the effect of additional options to reduce GHG emissions from Welsh agriculture (using the ADAS model)
- Determine the baseline spatial GHG emissions and soil carbon storage across Wales, and assess the effects of reducing N fertiliser use on GHG emissions, and the impacts of a changing climate would have on GHG emissions and soil carbon storage (ECOSSE model)
- Evaluate the barriers that may exist which limit uptake of woodland creation options in Glastir
- Determine the wider benefits of the Glastir Efficiency Scheme grants on i) socio-economics of the farm and rural communities within Wales, and ii) farm carbon footprints.

## 6.3. Year 2 Highlights

### *6.3.1 Carbon Footprinting*

- On this set of 16 Welsh model farms, the 4 Glastir options explored is projected to have had the intended effect of reducing GHG emissions and (in most cases) increasing C-sequestration in biomass and soils.
- The effectiveness of the different options in reducing GHG and increasing C sequestration varied between farm types.
- The tool indicated the GHG reductions were mediated primarily through reductions in livestock, with small additional reductions associated with lower requirements for farm inputs associated with stock management. These reductions to inputs extend the impact of the scheme option beyond the boundaries of the participating farm, and into the upstream agricultural supply chain.
- Reductions in livestock numbers may or may not lead to reductions in farm productivity and hence the economic and supply performance of the farm, although this is difficult to predict with confidence.
- The tool indicated the conversion of grassland to woodland resulted in a net increase in carbon sequestration but the overall impact of the “woodland margin extension” and “streamside corridor” options is limited by the small number of farms with applicable land.

### *6.3.2 Effects of Reduced Fertiliser N Use and Climate Change on Spatial GHG Emissions*

- The ECOSSE model differs with respect to the models used in the GMEP Year 1 scenario work in that is a process-based model ,so is capable of quantifying changes to GHG emissions in the longer term when emission factors which underpin other models may change e.g. in response to climate change. These models are the ideal but require a great deal of data and there remain uncertainties in the science and the scale of results is significantly reduced compared to the other models.
- ECOSSE estimated the mean annual net GHG balance at baseline climate of 0.2 t $CO_2e$ /ha/y.
- The Glastir option of reducing N fertilizer to reduce GHG and soil organic carbon (SOC) fluxes could reduce the annual net GHG balance from 0.20 to 0.17 (for a 20% N reduction), and to 0.15 (for a 40% N reduction) t $CO_2e$ /ha/y, respectively.

- The model indicated climate change will not significantly affect net GHG fluxes from Welsh soils or Net Primary Productivity by vegetation by 2050. This is primarily a result of the small differences between the baseline and 2050 climate scenarios (about ±2%).

### *6.3.3 Simultaneous Measurements of nitrous oxide, methane and carbon dioxide from Welsh grasslands*

- Methane and carbon dioxide fluxes are now being measured, with nitrous oxide measurements to follow imminently.

## 6.4 Methods

### *6.4.1 Carbon Footprinting*

The Bangor carbon footprinting (CF) tool was used to estimate which type of farm is responsible for the greatest GHG emissions and C sequestration, and also to evaluate the potential effects of a limited number of Glastir options on GHG emissions and C sequestration. The approach include indirect or embedded sources of emissions which are not included in the IPCC methodology for country level greenhouse gas emission inventories.

The CF tool takes real farm data on all inputs, land management practices (and history for Land Use Change) and monthly stock diary data to generate annual C footprints that are PAS 2050 compliant (unless soil and biomass C sequestration effects are included). It adopts simple, default (Tier 1 ) emission factors for most $N_2O$ and $CH_4$ emissions (enteric fermentation based on animal category numbers and bodyweights x average EFs; soil emission factors; manure storage by type *etc*…). But it includes a slightly more complex (Tier 2) estimate of soil C accumulation under grassland, and accounts for on-going C sequestration in tree biomass. A monthly stocking diary enables more accurate estimation of annual enteric fermentation (x animal numbers) and manure management (N excretion and $CH_4$ EFs). It takes a Life Cycle Analysis approach, and takes account of embedded GHG emissions associated with feed and fertiliser production and transportation to the farm.
The CF tool was used to determine individually the effects of the following Glastir options: Grazed Permanent Pasture – No Inputs; Grazing Management of Open Country; Woodland margin extension; Create New Streamside Corridor – Both Sides / Tree Planting, on GHG emissions and C sequestration.

### *6.4.2 Estimating Effects of Reduced N Fertiliser Use and Climate Change on Spatial Emissions of Greenhouse Gases*

The Welsh Government is committed to reduce greenhouse gas emissions from agricultural systems. One of the Glastir options is to reduce fertiliser application rates, specifically to remove nitrogen (N) inputs to some fields. Since N fertiliser applications to soil represent a key source of the greenhouse gas nitrous oxide ($N_2O$), a reduction in fertiliser nitrogen use will result in a reduction in the production and loss of this gas. The ECOSSE model was applied to estimate the effect of reducing fertiliser N use across Wales on the net soil greenhouse gas balance, i.e. on the difference between the sum of $N_2O$ and $CH_4$ fluxes, minus the change in soil organic carbon (SOC) (as $CO_2$).
The ECOSSE model was developed to simulate highly organic soils similar to those found in Wales. ECOSSE uses data describing climate, plant inputs, nutrient applications and timing of management operations to drive the model and simulate carbon sequestration and soil GHG emissions (note ECOSSE does not simulate methane emissions from ruminant livestock and their manures, but does estimate methane emissions from waterlogged soils). The decomposition process results in $CO_2$ and $CH_4$, with $CO_2$ losses dominating under aerobic conditions and $CH_4$ losses under anaerobic conditions. The spatial simulation of GHG and SOC fluxes is carried out for Wales on a 1 $km^2$ soil grid

basis using 5 dominant soil types in each grid cell. The model output represents the area-weighted mean of the simulations carried out for each soil type in the grid cell. The Land Cover Map (LCM2007; 8) was applied, and four main ecosystems were simulated (arable, grassland, forest and natural).

The model was applied spatially using Welsh soil data 2005 and UKCP09 climate data (1961-1990) as inputs data. The arable and grass lands are assumed to be fertilised whilst the forest and natural lands are assumed to remain unfertilised. Results were reported in terms of $CO_2$-equivalent values ($CO_2$e) using the IPCC 100-year global warming potentials (GWPs). We report a net greenhouse gas balance. A positive net greenhouse gas balance is harmful and a negative net GHG balance is beneficial.

### *6.4.3 Simultaneous measurements of $N_2O$, $CH_4$ and $CO_2$ from Welsh grasslands*

All greenhouse gases from soil are produced by microbial processes and thus are sensitive to environmental conditions such as soil moisture and temperature. Ruminant methane emissions are controlled by factors such as age and type of livestock, dietary composition and intake rate. These environmental factors contribute to natural variability in greenhouse gas emissions. However, human activities such as fertilisation, livestock management, drainage and land-use change have greatly altered these natural cycles, commonly leading to increases in emissions.

In the GMEP project, we have procured state-of-the-art analysers capable of simultaneously quantifying small changes in atmospheric concentrations of $N_2O$, $CH_4$ and $CO_2$, for quantifying fluxes of GHGs using Eddy Covariance. This unique measurement system for quantifying $N_2O$, $CH_4$ and $CO_2$ is the first of its kind in Wales, and has been challenging in its development. Delays in procurement of specialist analysers and complex integration of hardware and software has delayed deployment to the grassland farms in Wales.

The analysers have been set up in mobile laboratories that have now been towed to a commercial farm to assess the relative importance of environmental conditions and management practices on the emissions of $CH_4$ and $CO_2$. $N_2O$ and soil moisture analysers are being integrated and will be deployed to the commercial farm imminently. These unique measurements will contribute to our understanding of the impact of Glastir management practices on net carbon balances of grazed pastures.

## 6.5 Results

### *6.5.1 Carbon Footprinting*

#### *6.5.1.1 Baseline GHG emissions and C sequestration from different farm types*

Methane dominated direct GHG emissions (i.e. compared to $N_2O$ emissions), with >2 times the direct $CO_2$e arising from $CH_4$ compared to $N_2O$ in the beef, dairy and mixed farms. On the sheep farms, contributions of $CH_4$ and $N_2O$ emissions to the total direct GHG emissions were more similar.
At the farm level, 19-36% of total GHG emissions are embedded GHG emissions associated with imported feed, manufacturing of fertiliser and livestock purchases.

Total GHG emissions per hectare ($CO_2$e/ha) were greatest from the dairy farms, with similar total $CO_2$e emissions/ha from the Beef and mixed farms, and least from the sheep farms (Table 6.5.1.1.1). At the farm level, the major sink for carbon is soils under grassland (62 -82 % of total C sequestration), with woodland, other trees and hedgerows providing the remaining C sequestration. Total C sequestration rates appear to be lower in the Mixed farms compared to the Beef and Dairy farms (Table 6.5.1.1.1).

| kg $CO_2e$/ha | Mean total GHG emissions | Standard error of the mean | Mean total C sequestration | Standard error of the mean |
|---|---|---|---|---|
| Beef (4) | 6,464 | 867.1 | 1,354 | 517.6 |
| Dairy (4) | 11,237 | 1,314.3 | 1,401 | 358.5 |
| Mixed (3) | 8,334 | 1,208.4 | 838 | 102.7 |
| Sheep (4) | 1,699 | 405.5 | 1,070 | 122.6 |

**Table 6.5.1.1.1** *Typical total GHG emissions per hectare from different farm types in Wales (kg $CO_2e$/ha).*

### *6.5.1.2 Effects of Glastir Options on GHG Emissions and C Sequestration*

#### 6.5.1.2.1 Zero inputs

Reducing nitrogen inputs to grazed permanent grassland reduces the carrying capacity of the grassland, and therefore animal numbers carried by the farm. Overall, the tool calculated GHG emissions for the 15 farms were reduced by an average of 7%,. This scheme option affected land use primarily through the effects of land-use change, which in this case increases soil C sequestration under grassland by removing and reducing nitrogen inputs. The net impact on carbon sequestration was an increase of 6% overall; with the largest impacts on the more extensive beef and sheep farms (4.5% and 17% respectively) and a much smaller impact on the dairy and mixed farms (1.4% and 2.5%) because of their lower proportion of permanent grassland.

#### 6.5.1.2.2 Grazing Management of Open Country

Sheep numbers reduced by 13% overall; with smaller reductions where sheep were the secondary enterprise (beef farms 7%, dairy farms 14%). Overall, GHG emissions for the 10 affected farms on which this option was applied was calculated to be reduced by an average of 5%. This scheme option result in no effects which could be modelled regarding the effect on C sequestration, since no land management change was applied.

#### 6.5.1.2.3 Woodland Margin Extension

The land area converted from grassland to woodland was very small. Modelled nitrogen reductions averaged 1.5% and livestock were reduced by only about 1%. Reducing livestock numbers has a consequential effect on modelled productivity, with meat sales down by 0.5% and milk by 3.8%. Overall, GHG emissions for the five farms were calculated to have been reduced by an average of 1.5%.. The modelled conversion of grassland to woodland has a net positive impact on C storage although the farm impacts are small (an average increase of 0.03%) because woodland boundary length (i.e. applicable land area for this option) on most farms is small.

#### 6.5.1.2.4 Create New Streamside Corridor – Both Sides / Tree Planting

The land area converted from grassland to woodland was very small. Nitrogen reductions modelled were less than 0.5% and livestock were reduced by only 0.02%. Overall, GHG emissions for the five farms were calculated to have been reduced by an average of 0.11%, or 1.4 metric tonnes of $CO_2$ equivalent per annum. The modelled conversion of grassland to woodland has a net positive impact on C storage although the farm impacts are small because riparian boundary length (i.e. applicable land area for this option) on most farms is small.
The full report with detail of the Carbon Footprinting of model Welsh Farms can be found as Appendix 6.1.

### *6.5.2 Estimating Baseline Soil-Borne GHG Emissions and Effects of Reduced N Fertiliser Use and Climate Change on Spatial Emissions of Greenhouse Gases*

*6.5.2.1 Baseline Emissions*

The map below (Figure 6.5.2.1.1) illustrates the simulated net GHG fluxes **(**t $CO_2$e /ha/y) from Welsh land use at baseline climate scenario 1961-1990 using the ECOSSE model. Nitrous oxide fluxes were the highest and major contributor to the net GHG balance especially for the grass and arable ecosystems, where N fertilizer was applied. However, fluxes of $N_2O$ from the forest and natural ecosystems were low and contributed less to net GHG balance. Fluxes of $CH_4$ and SOC were very low and represent a small sink for atmospheric C. The model underestimated $CH_4$ fluxes from saturated areas due to lack of observed spatial data on water table depth.

The overall average net GHG balance combining all gas fluxes was projected by the model as 0.198 t $CO_2$e/ha/y. The highest emitters are the grass and arable ecosystems with net GHG balance of 0.449 and 0.205 t $CO_2$e/ha/y, respectively. However, the net fluxes from the forest (0.053 t $CO_2$e/ ha/y) and natural (0.086 t $CO_2$e/ha/y) ecosystems are relatively small compared with that from the grass and arable ecosystems. Considering the net GHG balance of 0.198 t $CO_2$e/ ha/y, and the Welsh land use area of 1857690 ha (NS, 2004), the calculated annual net fluxes for the whole of Wales based on landuse in agriculture and forestry sectors at baseline climate (1961-1990) is 0.37 Mt $CO_2$e/y. It should be remembered that these estimates include emission sources not included in the Agriculture and LULUCF inventories.

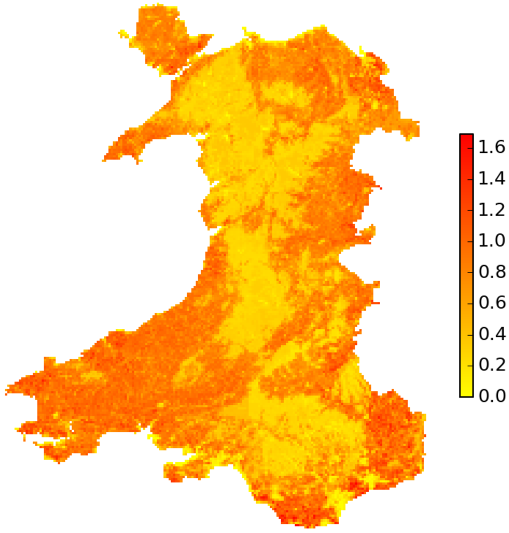


**Figure 6.5.2.1.1** *Greenhouse gas emissions (t $CO_2$e /ha/y) at baseline climate (1961-1990) from Welsh soils as projected by the ECOSSE model.*

*6.5.2.2 Effects of predicted climate change on soil-borne GHG emissions in Wales*

If the current N fertilizer application rate continues, future climate change by the year 2050 would not significantly affect the net GHG fluxes or net primary production (NPP) from Welsh soils according to the ECOSSE model. The difference between the two climate scenarios is, however, small (±2%). These results are explained in more detail in Appendix 6.2.

*6.5.2.3 Effects of Reduced N Fertiliser Use on Soil-Borne GHG Emissions from Wales*

Table 5.5.2.3.1 summarises the net effect of reductions in fertiliser N use by 20% and 40% on the net GHG balance as projected by the ECOSSE model. Reducing N fertilizer by 20% and 40% from the baseline resulted in 13% and 22% less $N_2O$ fluxes and thereby, lower net greenhouse gas (GHG) balance (Table 6.5.2.3.1). However, in this study, methane production and SOC fluxes were not much affected by reducing N fertilizer. The amounts of net $CH_4$ and SOC fluxes, under all fertilisation scenarios, represented a small sink for the atmospheric C. Nitrous oxide has a high global warming potential (GWP), thus reducing its emissions would result in beneficial change to net GHG balance. Mineral N has a direct influence on $N_2O$ production by provision of N for both nitrification and denitrification. The spatial variability in $N_2O$ fluxes is high and controlled by interacting abiotic and biotic factors, such as plants, micro-organisms, precipitation and nutrients. The flux is also expected to vary on a temporal basis depending on the dominant controlling factor.

| **(kt $CO_2$e)** | **Grasslands** | **Arable lands** | **Forestry** | **Natural lands** | **Net GHG balance ($CO_2$e)** |
|---|---|---|---|---|---|
| Baseline | 817 | 372 | 93 | 204 | 368 |
| 20% N reduction | 687 | 316 | n/a | n/a | 321 |
| 40% N reduction | 613 | 260 | n/a | n/a | 286 |

**Table 6.5.2.3.1** *Effects of fertiliser N reduction on the $N_2O$ emissions and Net GHG balance for Welsh soils as projected by the ECOSSE model. The Welsh land use area of 1,857,690 ha has been used in the calculations (kt $CO_2$e).*

A comprehensive report of the ECOSSE modelling can be found as Appendix 6.2

## 6.6 Future Plans

### *6.6.1 Year 3*

#### *6.6.1.1 Carbon Footprinting*

Options for further work depending on resource availability includes:

- Locate the major land owner (farmer) in selected visited/surveyed 1 $km^2$ and conduct C footprints for their farms as a baseline, then repeat in 4 years' time. This will provide an indication of the effects of changes in farm management (as a result of Glastir or not, farms could be targeted to be in and out of Glastir) on C footprints. This adds value to the farms that GMEP is already investing its resources in.
- Identify farms in Wales for which we have little information within the current C footprinting data base, e.g. arable. Footprint a cohort of these to allow future scenario testing across Wales.
- Conduct C footprinting on typical farm types in Wales to generate 'per ha' footprints for use in scaling effects of Glastir options – this could also coincide with farms on which the flux towers will be making measurements, i.e. the flux measurements would provide some validation data for this C footprinting in those fields (and source area) where measurements are made.
- Quantify $N_2O$, $CH_4$ and $CO_2$ fluxes from grassland fields using Eddy Covariance. Data will be used in the generation of net carbon balances for a range of intensities of grasslands. In field campaigns of 2-3 weeks will quantify $N_2O$, $CH_4$ and $CO_2$ fluxes from improved and unimproved upland grassland aligned with key on-farm management practices (e.g. livestock turnout, fertiliser/manure applications?). Where possible we will attempt to quantify the effects of Glastir options on these emissions.